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Which Executive Functioning Deficits Are Associated With AD/HD, ODD/CD and Comorbid AD/HD+ODD/CD?

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This study investigated (1) whether attention deficit/hyperactivity disorder (AD/HD) is associated with executive functioning (EF) deficits while controlling for oppositional defiant disorder/conduct disorder (ODD/CD), (2) whether ODD/CD is associated with EF deficits while controlling for AD/HD, and (3) whether a combination of AD/HD and ODD/CD is associated with EF deficits (and the possibility that there is no association between EF deficits and AD/HD or ODD/CD in isolation). Subjects were 99 children ages 6–12 years. Three putative domains of EF were investigated using well-validated tests: verbal fluency, working memory, and planning. Independent of ODD/CD, AD/HD was associated with deficits in planning and working memory, but not in verbal fluency. Only teacher rated AD/HD, but not parent rated AD/HD, significantly contributed to the prediction of EF task performance. No EF deficits were associated with ODD/CD. The presence of comorbid AD/HD accounts for the EF deficits in children with comorbid AD/HD+ODD/CD. These results suggest that EF deficits are unique to AD/HD and support the model proposed by R. A. Barkley (1997).

KEY WORDS: attention deficit/hyperactivity disorder; oppositional defiant disorder; conduct disorder; executive functioning; verbal fluency; working memory; planning.

Attention deficit/hyperactivity disorder (AD/HD), characterized by symptoms of distractibility, hyperactivity, and impulsivity, is one of the most prevalent and well-studied childhood psychopathological conditions. In one of the major contemporary theoretical explanations, this disorder is postulated to arise from a deficit in executive functioning (EF) (Barkley, 1997; Pennington & Ozonoff, 1996). EF encompasses meta-cognitive processes that enable efficient planning, execution, verification, and regulation of goal-directed behavior. There is no single agreed upon definition of EF. The frontal cortex and its subcortical connections have been suggested to serve as the major neurological underpinnings for EF (Eslinger, 1996; Lezak, 1995; Pennington & Ozonoff, 1996). Interestingly, several studies have suggested abnormalities in the structure and activation of these structures in AD/HD (Biederman & Spencer, 1999; Castellanos et al., 1996, 2002; Pennington & Ozonoff, 1996; Riccio, Hynd, Cohen, & Gonzalez, 1993; Shaywitz, Fletcher, Pugh, Klorman, & Shaywitz, 1999). Recent reviews of the literature on EF in AD/HD indicate that the evidence for EF deficits in AD/HD is inconclusive (Pennington & Ozonoff, 1996; Sergeant, Geurts, & Oosterlaan, 2002).

A key question in the last decade has been whether EF deficits are specific to AD/HD or whether such deficits are also associated with other disruptive behavior disorders (DBDs), i.e., oppositional defiant disorder (ODD) and conduct disorder (CD) (Pennington & Ozonoff, 1996). Impairments in EF have also been reported in children with ODD or CD, here denoted as ODD/CD (for reviews, see Moffitt, 1993; Morgan & Lilienfeld, 2000; Pennington & Ozonoff, 1996; Sergeant et al., 2002; also see Déry, Toupin, Pauzé, Mercier, & Fortin, 1999; Haggerty, Nevid, & Moulton III, 1998; Oosterlaan, Logan, & Sergeant, 1998; Séguin, Boulerice, Harden, Tremblay, & Pihl, 1999; Séguin, Pihl, Harden, Tremblay, & Boulerice, 1995; Speltz, DeKlyen, Calderon, Greenberg, & Fisher, 1999).

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However, in contrast to the extensive literature on EF deficits in AD/HD, research addressing EF deficits in ODD/CD is scarce. Indirect support for EF deficits in ODD/CD comes from studies into antisocial behavior in adults (for review, see Morgan & Lilienfeld, 2000; also see Giancola, Mezzich, & Tarter, 1998; Giancola & Zeichner, 1994; Lau, Pihl, & Peterson, 1995; Moffitt, Lynam, & Silva, 1994). ODD/CD is seen as a possible precursor for antisocial behavior in adults (Lynam, 1998).

Since both AD/HD and ODD/CD seem to be associated with EF deficits, the question is raised how these two different disorders can share the same deficit. AD/HD and ODD/CD have been found frequently to co-occur (e.g., Angold, Costello, & Erkanli, 1999). If impairments in EF are only present in AD/HD, the association between EF deficits and ODD/CD may be an artifact of the presence of comorbid (subthreshold) AD/HD in the ODD/CD samples studied. Likewise, if only ODD/CD carried the deficits in EF, the reported EF impairments in children with AD/HD may be due to the high prevalence of ODD/CD in these children. Finally, impaired EF may underlie both disorders. The majority of previous studies have not controlled for comorbidity. Therefore, problems arise in the interpretation of these studies. On the basis of a review of the literature, Pennington and Ozonoff (1996) concluded that those studies finding support for EF deficits in children with ODD/CD failed to control for comorbid AD/HD. In other words, Pennington and Ozonoff argued that the presence of comorbid AD/HD accounted for the EF deficits in children with ODD/CD.

Several studies support the hypothesis of Pennington and Ozonoff (1996) that AD/HD, but not ODD/CD, is associated with deficits in EF. With almost 400 children included, the study by Klorman et al. (1999) is the largest study that reported on the specificity of EF deficits in AD/HD. In that study evidence was found for planning deficits as measured with the Tower of Hanoi (ToH) in children with AD/HD combined type, but not in children with AD/HD inattentive type. Interestingly, ODD was associated with superior performance on the ToH. Set-shifting as measured by the Wisconsin Card Sorting Test (WCST), did not discriminate between groups. Clark, Prior, and Kinsella (2000) compared adolescents with AD/HD, ODD/CD and comorbid AD/HD+ODD/CD with normal controls on two EF measures. Adolescents with AD/HD performed worse than adolescents without AD/HD, whether or not they also had ODD/CD. In a subsequent study using the same diagnostic groups of children, Kalff et al. (2002) obtained similar results using three different measures of working memory. Poor performance on these measures was only evident in children with a diagnosis of AD/HD whether or not they also had ODD/CD. A number of studies have compared children with AD/HD and ODD/CD on the Stop Task, a measure of response inhibition. In a meta-analysis of these studies, Oosterlaan et al. (1998) concluded that both disorders are associated with inhibitory deficits, although the evidence for AD/HD is stronger than for ODD/CD. A number of more recent studies, however, reported data rejecting this conclusion, by showing that AD/HD, but not ODD/CD, was associated with inhibitory dysfunction (Kooijmans, Scheres, & Oosterlaan, 2000; Oosterlaan & Sergeant, 1998a, 1998b; Schachar, Mota, Logan, Tannock, & Klim, 2000).

There is also some support for the hypothesis that ODD/CD, but not AD/HD, is associated with deficits in EF. Déry et al. (1999) compared adolescents with CD and CD + AD/HD and a normal control group on six measures of EF and found that both CD groups performed poorly on a test of verbal fluency. However, no differences were found for the other measures of EF. Other studies found evidence for EF deficits in ODD/CD while statistically controlling for AD/HD (Séguin et al., 1999; Toupin, Déry, Pauzé, Mercier, & Fortin, 2000).

Other studies are consistent with the idea that both AD/HD and ODD/CD are associated with EF deficits. In a study with adolescents, MacLeod and Prior (1996) found that AD/HD as well as CD were associated with poor performance on the Stroop Task, a measure of interference control. Aronowitz et al. (1994) studied a sample of adolescents with ODD, CD and AD/HD, most of whom showed a combination of these diagnoses. A diagnosis of CD was associated with poor performance on the WCST and the Rey-Osterreith Complex Figure Test, a task that places demands on several aspects of EF. AD/HD was associated with poor performance on the WCST only.

Finally, some older studies by Moffitt and colleagues (Moffitt & Henry, 1989; Moffitt & Silva, 1988) suggest that only children with a diagnosis of both AD/HD and ODD/CD show EF deficits. In these studies it was found that neither children exhibiting delinquency nor children with AD/HD were impaired on a battery of EF measures. Only children who were both delinquent and had AD/HD were found to be impaired. These studies differ from the mainstream of studies reviewed here in that DSM diagnoses were not established.

All in all, relatively little research has been conducted attempting to differentiate AD/HD and ODD/CD in terms of EF, and those studies that did have produced mixed results. The conflicting results may be related to the use of small samples, the criteria used to select subjects, the differences in the domains of EF assessed, and differences in the procedures used to assess EF.

The present study was designed to address three issues: (1) whether AD/HD is associated with EF deficits while controlling for ODD/CD, (2) whether ODD/CD is associated with EF deficits while controlling for AD/HD, and (3) whether a combination of AD/HD and ODD/CD is associated with EF deficits (and the possibility that there is no association between EF deficits and AD/HD or ODD/CD in isolation). Three putative domains of EF were investigated: verbal fluency, working memory, and planning (Barkley, 1997; Pennington & Ozonoff, 1996).

Because of the overlap between the concept of EF and the anatomical region of the frontal cortex, Pennington and Ozonoff (1996) suggested validating EF measures in terms of their demands on frontal cortex functioning. From this perspective, only measures that have been shown to rely heavily on frontal cortex functioning should be used to study EF. On the basis of this criterion, three measures were selected for the present study: verbal fluency, the Tower of London (ToL), and the Self-Ordered Pointing Task (SOPT).

While a number of studies have examined EF deficits in children with AD/HD, ODD/CD or comorbid AD/HD + ODD/CD, the unique contribution of this study is that it directly compares the impact of all three psychopathological conditions in terms of different domains of EF. With the exception of verbal fluency, the SOPT and the ToL have not been applied in samples of children with ODD/CD.

METHOD

Participants and Selection Procedures

This study reports the data of 99 children, 73 boys, and 26 girls. Mean age was 10.3 years ($SD = 1.5$, range 7–13 years). There were 61 children with DBDs and 38 normal controls. The mean estimated Full Scale IQ was 97.4 ($SD = 19.2$, range 70–151).

Disruptive children were selected from 14 schools specialized in the education of children with extreme externalizing behavior problems. Of all Dutch children in the age range of 6–12 years, 2.1% are referred to these schools because of their disruptive behavior (Central Office for Statistics, 2002). The normal control children were selected from six regular schools. Schools were located throughout the country. All parents of children attending the schools received information on the study. Parents willing to allow their child to participate in the study, signed an informed consent form and completed a set of questionnaires. Next, teachers filled out a set of questionnaires for those children for whom informed consent was obtained.

Parent and teacher questionnaires were used to select children for this study. Parents completed two rating scales: (1) the DBD rating scale (Oosterlaan, Scheres, Antrop, Roeyers, & Sergeant, 2000; Pelham, Gnagy, Greenslade, & Milich, 1992), a symptom severity rating scale containing four scales with the behavioral descriptors of AD/HD inattentive subtype, AD/HD hyperactive-impulsive subtype, ODD as well as CD according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; American Psychiatric Association [APA], 1994) and (2) the Child Behavior Checklist (CBCL; Achenbach, 1991; Verhulst, Van der Ende, & Koot, 1996a). Teachers completed three rating scales: (1) the DBD, (2) the Teacher Report Form (TRF; Achenbach, 1991; Verhulst, Van der Ende, & Koot, 1996b) and (3) the IOWA Conners Teacher Rating Scale (IOWA CTRS; Oosterlaan, Prins, & Sergeant, 1992; Pelham, Milich, Murphy, & Murphy, 1989). The response rate for parents and teachers was 38.3% and 89.6%, respectively.

Children with DBDs were selected using the DBD. Specifically, children were included in the study if *at least one* of the following criteria was met for *both* parent and teacher DBD ratings: (1) a rating of 12 or more on the Inattention scale and/or on the Hyperactivity/Impulsivity scale, (2) a rating of 8 or more on the ODD scale, or (3) a rating of six or more on the CD scale. Cutoffs were calculated from the number of DSM-IV symptoms required for diagnosis multiplied by two (item scored as 'applies pretty much,' see Pelham et al., 1992). In a large normative sample (Oosterlaan et al., 2000), these cutoffs were equivalent to a score above the 90th percentile on all scales for all informants, with the exception of the ODD parent scale for which the cutoff translated into a score above the 80th percentile. In order to exclude children with psychotic symptoms, an additional criterion for all children was that the child was rated at or below the 75th percentile on the Thought Problem scale of the CBCL and the TRF.

Normal controls were selected using the DBD, CBCL and TRF. To be eligible for the study normal children had to meet three criteria: (1) scores below the critical values on all scales of both the parent and teacher DBD, (2) scores at or below the 75th percentile on all the scales of the CBCL and the TRF, and (3) scores below the suggested cutoff scores on the Inattention/Overactivity scale and the Oppositional/Defiant scale of the IOWA CTRS (Pelham et al., 1989).

Children who used medication that could not be discontinued and that might have interfered with performance on the EF tasks were excluded from the study. Eleven disruptive children used methylphenidate, but discontinued the use of this medication at least 18 hours prior to the experiment in order to allow a complete washout (Barkley, DuPaul, & Connor, 1999). All children had normal hearing and normal or corrected vision. The study was approved by the University Ethics Committee and informed consent was obtained from parents. Children received a small gift (worth approximately USD 1) for participating in the study.

EF Tasks and Dependent Measures

Verbal Fluency

Verbal fluency measures the ability to generate a novel strategy under a time constraint for guiding an organized search of the internal semantic network (Eslinger, 1996; Lezak, 1995; Welsh, Pennington, & Groisser, 1991). Fluency of speech is typically measured by the quantity of words produced within a given time period that either begin with a given letter (letter word fluency) or belong to a restricted semantic category (semantic word fluency).

A number of studies, including studies with brain damaged adults, as well as studies using functional magnetic resonance imaging and positron emission tomography have shown that this task is sensitive to prefrontal cortex functioning. Verbal fluency tends to be associated in particular with functioning of the left prefrontal cortex (for review, see Cohen, Morgan, Vaughn, Riccio, & Hall, 1999; also see Frith, Friston, Liddle, & Frackowiak, 1991; Gaillard et al., 2000; Parks et al., 1988; Phelps, Hyder, Blamire, & Shulman, 1997; Pujol et al., 1996; Schlosser et al., 1998).

In this study, an adaptation was used of the Controlled Oral Word Association Test (Benton & Hamsher, 1976). To measure letter word fluency, children were required to name as many words as possible beginning with the letters K and M (Pollux, Wester, & De Haan, 1995). To measure semantic word fluency, children were required to name as many examples of the categories 'animals' and 'food' (e.g., Barkley & Grodzinsky, 1994; Grodzinsky & Diamond, 1992; Nigg, Quamma, Greenberg, & Kusche, 1999; Reader, Harris, Schuerholz, & Denckla, 1994; Schuerholz, Baumgardner, Singer, Reis, & Denckla, 1996; Welsh et al., 1991). For each of the two letter and semantic categories, there was a time limit of 1 minute. Children were instructed to exclude names of persons and the same word with a different suffix. If inadmissible words were given, the children were briefly reminded of the rules. The dependent measure in this task was the total number of correct words, which was derived for letter and semantic word fluency separately.

SOPT (Abstract Designs)

The SOPT (Petrides & Milner, 1982) was used to assess working memory. This task requires that previous choices be constantly compared with choices that still remain to be carried out, thereby placing heavy demands on working memory. Working memory is the capacity to simultaneously store, process, and monitor information (Baddeley, 1996). Working memory guides subsequent actions, making these actions memory-guided rather than sensory-guided (Eslinger, 1996).

The SOPT is one of the rare tests that have been validated as a relative selective frontal cortex measure (Petrides, Alivisatos, Evans, & Meyer, 1993; Petrides & Milner, 1982; Shallice & Burgess, 1991). Petrides and Milner (1982) showed that patients with excisions of the dorsolateral frontal lobe performed poorly on this task, whereas patients with temporal lobe excisions (without damage to the hippocampus) performed normally. Furthermore, studies with positron emission tomography and magnetic resonance imaging have demonstrated that performance on the SOPT relies on the middorsolateral frontal cortex (Petrides et al., 1993).

In the SOPT, children were presented with four series of cards each containing 6, 8, 10, and 12 abstract designs, respectively. The designs were relatively easy to distinguish from one another, but difficult to code verbally. For a specific series, the number of cards was equal to the number of designs on each of the cards of that series. Thus, for the series with six designs, there were six cards with the six designs on each card. The same set of designs was printed on each card, but the position of these designs varied randomly from card to card. In the four series of cards, different designs were used.

The six design series was administered first, followed by the 8-, 10- and 12-series, respectively. For each series, children were presented with one card at a time. Children were instructed to point to a different design on each card. In addition, children were informed that they could point to the designs in any order they wished, but without pointing to one of the designs more than once. Following the administration procedure of Petrides and Milner (1982), each series was presented three times in succession. Children were instructed to work at a comfortable pace, while striving for accuracy. Children were not allowed to respond to the same location on consecutive trials, because by adopting such a strategy, the child would not need to identify the abstract design. Therefore, if children pointed to the same location on two consecutive trials, they were told that this strategy was not acceptable. Children were not informed of their errors. A series of three designs was used for practice. Testing began only when participants fully understood the instructions.

The dependent variable in this task was the number of errors as measured by the number of times a design was responded to more than once (Daigneault & Braun, 1993; Shue & Douglas, 1992). The number of errors was calculated separately for difficulty level (6, 8, 10, and 12 designs). The demand on working memory increases as the number of cards and the number of designs on each card increases progressively during the task. Hence, it was expected that the number of errors would show a linear relation with difficulty level. A deficit in working memory would become evident in a relatively strong increase in the number of errors with increasing difficulty level.

Tower of London

Planning ability was investigated using the ToL, an adaptation of the ToH. This task requires the subject to generate and execute a sequence of moves to solve a problem. Planning is aimed at the attainment of a future goal through a sequence of steps, which do not necessarily lead directly to that goal. It requires the subject to anticipate consequences of one course of action on another, and monitor goal attainment (Baker et al., 1996).

Several studies suggest that ToL performance relies heavily on frontal cortex functioning, and left frontal cortex functioning in particular (Baker et al., 1996; Carlin et al., 2000; Dagher, Owen, Boecker, & Brooks, 1999; Elliott, Frith, & Dolan, 1997; Levin et al., 1993, 1994; Morris, Ahmed, Syed, & Toone, 1993; Owen, Downes, Sahakian, Polkey, & Robbins, 1990; Rezai et al., 1993; Rowe, Owen, Johnsrude, & Passingham, 2001; Shallice, 1982). These studies employed patients with well-defined brain lesions and normal controls performing the ToL, while using single-positron emission computerized tomography and positron emission tomography.

Materials and procedures for administration and scoring of the ToL were taken from Krikorian, Bartok, and Gay (1994). The ToL consists of three pegs of different lengths mounted on a strip, and three colored balls (red, blue, and yellow) that can be manipulated on the pegs. The longest peg can hold three balls, the middle peg can hold two balls, and the smallest peg can hold one ball. Starting from a fixed arrangement of the balls on the pegs, the child is required to copy a series of depicted end-states by rearranging the balls. A problem is solved correctly, when the end state is achieved within the minimum number of moves necessary to solve that problem, while avoiding errors. The demand for planning is manipulated by presenting problems that differ in the minimum number of moves required for solution. Upon presentation of a problem, participants were informed of the number of moves required to solve that problem correctly. Children were encouraged not to make the first move, until they were confident that they could execute the entire sequence of moves to solve the problem. A maximum of three trials was allowed to solve each problem. Children were told to strive for accuracy as well as speed. A practice problem was presented to familiarize the child with the task. This practice problem required two moves to reach a solution. Thereafter, 12 problems with graded difficulty were presented. There were two problems requiring at least two moves to be solved, two problems requiring at least three moves to be solved, four problems requiring at least four moves to be solved, and four problems requiring at least five moves to be solved.

Performance on the ToL was videotaped and scored afterwards for a number of dependent variables. The main dependent variable is the ToL score, which was calculated by assigning points based on the number of trials required to solve a problem. Three points were given if the problem was solved on the first trial, two points for successful solution on the second trial, and one point for successful solution the third trial. The ToL score is the sum of points for on all 12 problems. The maximum ToL score is 36.

Three additional dependent measures were calculated for each child. The number of errors was recorded to tap the quality of the child's performance. In addition, two temporal measures were obtained: (1) planning time, which is the time between the presentation of a problem and the initiation of the first move on a trial (ball leaves peg), and (2) execution time, which is the time between the initiation of the first move to the completion of the final move on a trial (regardless of whether a correct or an incorrect solution has been achieved). Latency measures were calculated separately for difficulty level. There were three difficulty levels: the lowest difficulty level consisted of those problems requiring at least two or three moves to be solved, the medium difficulty consisted of those problems requiring at least four moves to be solved, and the highest difficulty level consisted of those problems requiring at least five moves to be solved. The latency measures were analyzed to investigate the processes underlying performance on the ToL. It was expected that there would be a linear relation between the latency measures and difficulty level. Relatively short planning times may be indicative of poor planning and may lead to poor performance on the ToL. Relatively long execution times may reflect poor planning as well. If the sequence of moves to solve a problem is planned before initiation of the first move, execution time will be shorter compared to when the sequence of moves was not planned before, but after initiation of the first move. Data analyses were restricted to the first trial of each problem, because the second and third trials were presented only if the child failed to finish a problem in the minimum number of moves to solution. Thus, the latency measures were analyzed irrespective of the success of the attempted solution.

Revised Wechsler Intelligence Scale for Children

Two subtests of the Revised Wechsler Intelligence Scale for Children (WISC-R) were administered to all children: Vocabulary and Block Design (Groth-Marnat, 1997). The rationale for the selection of these two subtests was twofold. First, Vocabulary and Block Design may be used to estimate Full Scale IQ. Scores on both subtests correlate highly (.90 range) with Full Scale IQ (Groth-Marnat, 1997). In all analyses of EF measures, IQ was controlled to ensure that the results could not be explained in terms of IQ effects (Sergeant et al., 2002). Secondly, Vocabulary and Block Design measure some non-EF abilities which play a major role in performance on the EF tasks in the present study. More specifically, Vocabulary measures language development and word knowledge which are crucial non-EF demands in verbal fluency (Denckla, 1996; Groth-Marnat, 1997; Miller, 1984; Schuerholz et al., 1996). Block Design measures the ability to analyze a whole into component parts as well as spatial visualization (Groth-Marnat, 1997). These non-EF abilities figure prominently in performing on the ToL. Thus, entering IQ in the analyses of the EF measures allowed us to control for the possible confounding effects of some non-EF abilities.

There is dispute as to whether one should control for IQ or not. It has been argued that controlling for differences in IQ removes a portion of variance that is associated specifically with AD/HD (Nigg, 2001). Furthermore, there is debate about the overlap between the concepts of EF and IQ. Some authors suggest that EF and IQ show a large overlap (Duncan, Johnson, Swales, & Freer, 1997), while others argue that the concept of EF is largely unrelated to IQ (Nigg et al., 1999; Pennington & Ozonoff, 1996; Séguin et al., 1999; Welsh et al., 1991). However, correlations between measures of IQ and EF are rather low (Ardila, Pineda, & Rosselli, 2000), which implies that IQ is not the same as EF, but that there is some overlap between IQ and EF (Crinella & Yu, 2000). We argue that, if EF deficits in AD/HD were core deficits, these would remain even when IQ was controlled.

PROCEDURE

Test administrators were carefully trained and were blind to the child's group assignment except that administrators knew which children were included because of DBDs. Standardized instructions were used for all tests. Tests were administered in a fixed order. Children were tested individually in their own school in a quiet room.

Statistical Analyses

For two cases there were data missing for ToL planning time due to examiner error or child noncompliance. These data were replaced by group means. Analyses for planning time were rerun excluding cases with missing values. This analysis yielded similar results to that with these participants included. Both continuous (multiple regression) and categorical data analyses (ANCOVAs) were conducted. Groups differed in terms of gender and IQ, and the possible confounding effects of these variables were controlled in both types of analyses. Gender and IQ were entered as predictors in the regression analyses, whereas gender and IQ served as covariates in the ANCOVAs.

Continuous Data

Multiple regression analyses were used to evaluate how well symptoms of AD/HD and ODD/CD predicted performance on the EF tasks. To investigate whether a combination of AD/HD and ODD/CD is associated with EF deficits, the interaction between AD/HD and ODD/CD symptoms was entered in the regression analyses. To facilitate interpretation of possible interaction effects, ratings were dichotomised and the product of AD/HD and ODD/CD ratings was used as a predictor in the analyses. A distinction was made between parent and teacher reported symptoms because a substantial body of evidence suggests that both informants report on different aspects of behavior (Achenbach, McConaughy, & Howell, 1987; Hart, Lahey, Loeber, & Hanson, 1994; Loeber, Green, Lahey, & Stouthamer-Loeber, 1991; Offord et al., 1996) and that symptom reports of both informants may show different associations with neuropsychological deficits (Riccio et al., 1994).[3]

From the parent and teacher questionnaires, scales measuring symptoms of AD/HD, ODD and CD were used

[3]Regression analyses using data combined across informants yielded similar results. ADHD ratings significantly predicted poor performance in terms of ToL planning time and SOPT errors, and marginally significantly predicted poor performance in terms of the ToL score. None of the other main and interactive effects of ADHD and ODD/CD were significant. Furthermore, none of the ADHD subtype analyses using data combined across informants were significant. Detailed results are available from the first author.

to calculate four composite measures: parent reported AD/HD, teacher reported AD/HD, parent reported ODD/CD, and teacher reported ODD/CD. These composite measures were used in the multiple regression analyses. To this end, for each of the four composite measures, relevant rating scale scores were subjected to a principal component analysis and the first principal component was used to calculate a factor score for each subject. The principal component analysis on the three parent measures of AD/HD (CBCL Attention Problems scale, DBD Inattention and Hyperactivity/Impulsivity scales) yielded a single factor solution explaining 91.0% of the variance. For the four teacher measures of AD/HD (TRF Attention Problems scale, DBD Inattention and Hyperactivity/Impulsivity scales, IOWA CTRS Inattention/Overactivity scale) the first principal component accounted for 89.3% of the variance. The principal component analysis on the three parent measures of ODD/CD (CBCL Externalizing Behavior scale, ODD and CD scales of the DBD) yielded a single factor solution explaining 93.8% of the variance. Finally, for the four teacher measures of ODD/CD (TRF Externalizing Behavior scale, ODD and CD scales of the DBD, IOWA CTRS Oppositional/Defiant scale) the first principal component accounted for 95.6% of the variance.

Categorical Data

Using research diagnostic criteria, the children with DBDs were assigned to one of three groups: an AD/HD group ($n = 22$), an ODD/CD group ($n = 18$), and a comorbid AD/HD+ODD/CD group ($n = 21$). ODD and CD were combined because ODD is frequently found to be a developmental antecedent of CD, because the two disorders are related to the same risk factors, and because ODD is generally considered a milder form of CD (APA, 1994).

The parent and teacher DBD was used to assign children to one of the three groups. For a child to be included in one of the three psychopathological groups, both parent *and* teacher ratings had to meet inclusion criteria for that particular group. This procedure added reliability, minimized informant bias, and allowed the selection of children with pervasive behavior patterns. Specifically, inclusion criteria for the AD/HD group were a rating of 12 or more on the Inattention scale and/or on the Hyperactivity/Impulsivity scale of both the parent and the teacher DBD. Inclusion criteria for the ODD/CD group were a rating of eight or more on the ODD scale and/or a rating of six or more on the CD scale of both the parent and teacher DBD. To be assigned to the comorbid AD/HD+ODD/CD group, the criteria for assignment to both the AD/HD and the ODD/CD group had to be met. Cutoffs were calculated from the number of DSM-IV symptoms required for diagnosis multiplied by two (item scored as 'applies pretty much,' see Pelham et al., 1992). In a large normative sample (Oosterlaan et al., 2000), these cutoffs were equivalent to a score above the 90th percentile on all scales for all informants, with the exception of the ODD parent scale for which the cutoff translated into a score above the 80th percentile.

To investigate the effects of AD/HD, ODD/CD and the interaction between AD/HD and ODD/CD from a categorical perspective, the dependent variables in this study were analyzed using ANCOVAs with group as the between subjects factor. The group factor had two levels: AD/HD (present or absent) and ODD/CD (present or absent). Difficulty level was entered as a repeated measure within subjects factor for SOPT number of errors (four levels), ToL planning time (three levels), and execution time (three levels). Trend analyses were performed to model the form of the effects of difficulty level on these dependent measures. For the ANCOVAs effect sizes are reported in terms of eta square (η^2).

Following Cohen's guidelines (1988), effect sizes were defined in terms of the percentage of variance explained: 1, 9 and 25% were used to define small, medium, and large effects, respectively (these figures translate into η^2-values of .01, .06, and .14, respectively and into r-values of .1, .3, and .5, respectively). In all analyses α was set at .05.

RESULTS

Continuous Data

Verbal Fluency

For the letter word fluency task, the combination of the predictors did not account for a significant amount of the variability in the number of correct words, $R^2 = .12$, $F(8, 90) = 1.47$, *ns*. Furthermore, none of the individual predictors was significant. Thus, neither ODD/CD ratings nor AD/HD ratings independently or in combination predicted performance on the letter word fluency task. Similar findings were obtained for the semantic word fluency task. Although the combination of the predictors accounted for a significant amount of the variability in the number of correct words for the semantic word fluency task, $R^2 = .19$, $F(8, 90) = 2.59$, $p = .014$, IQ was the only predictor that was significant, $t(90) = 2.58$, $p = .011$.

SOPT (Abstract Designs)

Here the analyses focused on the increase in errors with difficulty level. In the analyses, performance at difficulty level 4 was taken as the criterion measure while performance at difficulty level 1 was controlled by entering this variable together with the other predictors. In this way the analyses focused on the predictive value of AD/HD, ODD/CD, and the interaction between AD/HD and ODD/CD for the increase in errors with difficulty level. The relationship between the criterion variable and the predictors was significant, $R^2 = .40$, $F(9, 89) = 6.61$, $p < .001$. Only teacher rated AD/HD significantly contributed to the prediction of accuracy on the SOPT, $t(89) = 2.80$, $p = .006$. The partial correlation between teacher rated AD/HD and number of errors, partialling out the effects of all other predictors, was .28.

Tower of London

With respect to the ToL score, the regression equation was significant, $R^2 = .22$, $F(8, 90) = 3.20$, $p = .003$. Both parent and teacher reported AD/HD significantly predicted the ToL score ($t(90) = 2.14$, $p = .035$ and $t(90) = 3.37$, $p = .001$, respectively). The partial correlation between parent reported AD/HD and the ToL score was .22, whereas the partial correlation between teacher rated AD/HD and the ToL score was −.34. Thus, parent and teacher ratings of AD/HD show a different relationship with the ToL score, with teacher ratings of AD/HD only being predictive of poor performance on the ToL. It should be noted that the zero-order correlations between the ToL score and both parent and teacher reported AD/HD were negative (−.14, and −.32, respectively).

For the analysis of the number of errors on the ToL as the criterion measure, the relationship with the predictors was significant, $R^2 = .29$, $F(8, 90) = 4.51$, $p < .001$. Teacher reported AD/HD and parent reported ODD/CD significantly contributed to the prediction of the criterion measure ($t(90) = 2.27$, $p = .026$ and $t(90) = 3.27$, $p = .002$, respectively). The partial correlation between teacher rated AD/HD and the number of errors was .23, whereas the partial correlation between parent reported ODD/CD and the number of errors was −.33. Thus, high teacher ratings of AD/HD were associated with a high error rate. In contrast, high parent ratings of ODD/CD were associated with a low error rate on the ToL.

With respect to ToL planning time, analyses focused on the increase in planning time with difficulty level. This was accomplished by taking performance at difficulty level 3 as the criterion measure and entering performance at difficulty level 1 in the first step together with the other predictors. The predictors accounted for a significant amount of the planning time variability, $R^2 = .18$, $F(9, 89) = 2.15$, $p = .033$. Only teacher rated AD/HD significantly contributed to the prediction of planning time on the ToL, $t(89) = 2.07$, $p = .041$. The partial correlation between teacher rated AD/HD and planning time was −.22.

Analogous to the analysis of planning time, execution time performance at difficulty level 1 was entered together with the other predictors, while performance at difficulty level 3 was the criterion variable. The combination of the predictors did not account for a significant amount of the variability in execution time on the ToL, $R^2 = .08$, $F(9, 89) = 0.88$, *ns*. None of the predictors was significant. Thus, neither ODD/CD ratings nor AD/HD ratings independently or in combination predicted execution time on the ToL.

AD/HD Subtypes

It has been suggested that EF deficits would be mainly evident in children with AD/HD combined and hyperactive-impulsive subtype, but not in children with AD/HD inattentive subtype (Barkley, 1997; Milich, Balentine, & Lynam, 2001). Exploratory hierarchical regression analyses were run to test this hypothesis. These analyses were identical to those described above, except that parent and teacher ratings of AD/HD and ODD/CD were replaced by parent and teacher measures of AD/HD inattention and AD/HD hyperactivity/impulsivity as measured by the DBD. None of the main and interactive effects were significant with a single exception: Teacher rated inattention significantly contributed to the prediction of SOPT number of errors, $t(87) = 2.23$, $p = .028$. The partial correlation between teacher rated inattention and SOPT number of errors was .23.

Categorical Data

The gender composition, ages, IQ scores, and rating scale scores for the four groups are shown in Table I.

There was a higher percentage of girls in the normal control group compared to the pathological groups. Groups did not differ with respect to age ($F(3,95) = .78$, *ns*, $\eta^2 = .02$). Pairwise group comparisons (Tukey; overall α set at .05) showed that the normal control group had a higher mean IQ than the three pathological groups. As expected, normal control children obtained the lowest

Table I. Means, Standard Deviations, and Pairwise Group Comparisons for Age, IQ, and Rating Scale Scores

	Group								
	AD/HD $n = 22(16)^a$		ODD/CD $n = 18(16)^a$		AD/HD + ODD/CD $n = 21(19)^a$		Normal controls $n = 38(22)^a$		
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	Pairwise group comparisons[b]
Age	10.0	1.5	10.5	1.3	10.7	1.5	10.3	1.6	*ns*
IQ	94.5	13.7	90.3	12.9	87.2	10.3	108.2	23.1	NC > AD, OD, CO
AD/HD–parent									
CBCL Attention Problems	70.5	6.9	64.7	8.1	72.2	8.0	51.0	2.0	CO, AD > OD > NC
DBD parent Inattention	14.4	5.0	11.3	4.5	14.5	4.9	1.7	2.3	CO, AD, OD > NC
DBD parent HI[c]	15.2	4.9	12.1	4.0	15.0	4.6	1.6	1.8	CO > NC; AD > OD > NC
AD/HD–teacher									
TRF Attention Problems	62.5	5.1	57.1	4.6	63.3	4.9	50.1	0.5	CO, AD > OD > NC
DBD teacher Inattention	14.6	3.9	7.1	3.1	14.8	3.8	0.4	0.8	CO, AD > OD > NC
DBD teacher HI[c]	13.5	4.5	7.4	4.3	13.8	4.5	0.5	1.4	CO, AD > OD > NC
IOWA CTRS IO[d]	8.2	2.2	5.3	2.5	8.5	2.4	0.5	1.2	CO, AD > OD > NC
ODD/CD–parent									
CBCL Externalizing Behavior	64.3	5.5	68.9	5.4	71.1	7.3	40.8	6.4	OD > NC; CO > AD > NC
DBD parent ODD	7.9	3.9	13.1	3.1	12.2	3.4	1.6	1.9	OD, CO > AD > NC
DBD parent CD	1.9	2.1	3.0	1.7	3.7	2.4	0.2	0.5	OD > NC; CO > AD > NC
ODD/CD–teacher									
TRF Externalizing Behavior	62.5	6.7	67.7	5.4	70.8	7.3	43.3	4.1	CO, OD > AD > NC
DBD teacher ODD	7.2	5.4	12.5	4.4	13.7	4.2	0.1	0.4	CO, OD > AD > NC
DBD teacher CD	2.0	2.8	4.5	3.5	4.9	3.7	0.0	0.0	CO, OD > AD > NC
IOWA CTRS OD[e]	4.6	3.1	7.1	2.0	7.3	2.8	0.1	0.4	CO, OD > AD > NC

Note. See main text for an explanation of the measures. AD = AD/HD; AD/HD = attention deficit/hyperactivity disorder; CBCL = Child Behavior Checklist; CD = conduct disorder; CO = comorbid AD/HD+ODD/CD; DBD = Disruptive Behavior Disorder rating scale; IOWA CTRS = Iowa Conners Teacher Rating Scale; NC = normal controls; ODD = oppositional defiant disorder; TRF = Teacher Rating Form.
[a]Number of males.
[b]All main effects for group: $F(3, 95)$, $p < .001$; pairwise comparisons with Tukey procedure (overall α set at .05).
[c]Hyperactivity/Impulsivity scale.
[d]Inattention/Overactivity scale.
[e]Oppositional/Defiant scale.

ratings of all groups on all relevant scales that were used for group assignment (parent and teacher DBD) as well as on the scales that were not used for subject classification (CBCL, TRF, and IOWA CTRS). The AD/HD and ODD/CD group differed in the expected direction on all scales, although differences on some scales did not reach conventional levels of significance. More specifically, the AD/HD and ODD/CD groups did not show significantly different scores on the CBCL Externalizing Behavior scales, and on the Inattention and CD scales of the parent DBD. The comorbid AD/HD+ODD/CD and the AD/HD group obtained similar ratings on scales measuring AD/HD. Furthermore, children with comorbid AD/HD+ODD/CD and children with ODD/CD obtained similar ratings on scales measuring ODD and CD symptoms. In general, findings support the behavioral distinctiveness of the four groups.

The group effects for the EF measures are summarized in Table II, and Figs. 1–3.

Verbal Fluency

For the number of correct words in the letter word fluency task, the effects of gender were not significant ($F(1, 93) < 0.01$, *ns*, $\eta^2 < .01$), but IQ was found to have a significant effect ($F(1,93) = 7.43$, $p = .008$, $\eta^2 = .07$). The main effects of AD/HD ($F(1, 93) = 0.54$, *ns*, $\eta^2 < .01$) and ODD/CD ($F(1, 93) = 3.49$, *ns*, $\eta^2 = .04$), as well as the interaction between AD/HD and ODD/CD ($F(1, 93) < .01$, *ns*, $\eta^2 < .01$) were not significant. None of the effects for semantic word fluency reached significance: nonsignificant results were obtained for IQ ($F(1,93) = 2.54$, *ns*, $\eta^2 = .03$), gender ($F(1, 93) = 0.11$, *ns*, $\eta^2 < .01$), AD/HD ($F(1, 93) = .03$, *ns*, $\eta^2 < .01$), ODD/CD ($F(1, 93) = 1.27$, *ns*, $\eta^2 = .01$), and the interaction between AD/HD and ODD/CD ($F(1, 93) = .11$, *ns*, $\eta^2 < .01$). These findings indicate that AD/HD, ODD/CD, and the combination of AD/HD and ODD/CD did not explain performance on the two verbal fluency tasks.

Table II. Results for Word Fluency and ToL

	Groups							
	AD/HD $n = 22$		ODD/CD $n = 18$		AD/HD+ODD/CD $n = 21$		Normal controls $n = 38$	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Letter word fluency number correct	16.0	5.1	14.5	5.4	13.7	3.6	16.8	6.6
Semantic word fluency number correct	35.9	6.8	33.5	8.4	34.4	9.2	36.2	8.0
ToL score	28.4	3.4	31.4	3.5	30.5	3.0	30.6	2.7
ToL number of errors	4.9	3.3	3.0	3.3	4.1	2.4	4.5	2.2

Note. Group means were adjusted for gender and IQ. AD/HD = attention deficit/hyperactivity disorder; ODD = oppositional defiant disorder; CD = conduct disorder; ToL = Tower of London.

SOPT (Abstract Designs)

IQ had significant effects on the number of errors in the SOPT ($F(1, 93) = 6.15$, $p = .015$, $\eta^2 = .06$). The effects of gender were not significant ($F(1, 93) = 1.37$, *ns*, $\eta^2 = .01$). Children with a diagnosis of AD/HD committed more errors than children without AD/HD ($F(1, 93) = 10.98$, $p = .001$, $\eta^2 = .11$). The number of errors on the SOPT showed a linear increase with difficulty level ($F(1, 93) = 208.97$, $p < .001$, $\eta^2 = .69$). As illustrated in Fig. 1, children with AD/HD (AD/HD present) showed a greater increase in the number of errors with difficulty level than children without AD/HD (AD/HD absent). This result was supported by a significant interaction between the linear effects of difficulty level and AD/HD ($F(1, 93) = 16.91$, $p < .001$, $\eta^2 = .15$). The interaction between the quadratic effects of difficulty level and AD/HD was also significant ($F(1, 93) = 5.43$, $p = .022$, $\eta^2 = .06$). All other main effects and interactions were not significant. Thus, children with AD/HD committed more errors on the SOPT and showed a greater increase in the number of errors with difficulty level than children without AD/HD. ODD/CD did not explain performance on the SOPT.

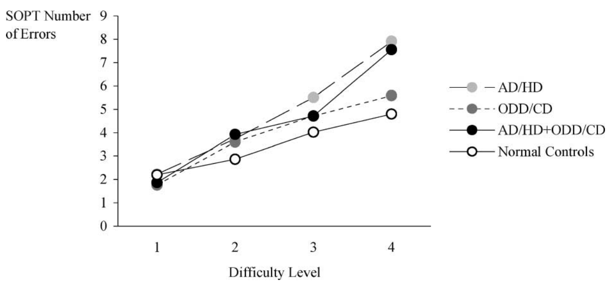

Fig. 1. The effects of difficulty level on the number of errors in the SOPT for children with AD/HD, ODD/CD, AD/HD+ODD/CD and normal controls.

Tower of London

With respect to the ToL score, the effects of IQ were not significant ($F(1, 93) = 3.42$, *ns*, $\eta^2 = .04$), but gender was found to have a significant effect ($F(1, 93) = 6.00$, $p = .016$, $\eta^2 = .06$). Children with a diagnosis of AD/HD obtained lower ToL scores than children without AD/HD ($F(1, 93) = 5.94$, $p = .017$, $\eta^2 = .06$). In contrast, children with a diagnosis of ODD/CD obtained higher ToL scores than children without ODD/CD ($F(1, 93) = 4.66$, $p = .033$, $\eta^2 = .05$). The interaction between AD/HD and ODD/CD ($F(1, 93) = 1.13$, *ns*, $\eta^2 = .01$) was not significant. This result indicates that both AD/HD and ODD/CD independently explained performance on the ToL (in terms of the ToL score): AD/HD is associated with poor performance on the ToL, whereas ODD/CD is associated with superior performance on this measure of planning.

No effects of IQ were found for the number of errors ($F(1, 93) = 2.33$, *ns*, $\eta^2 = .02$), but gender was found to have a significant effect ($F(1, 93) = 6.21$, $p = .014$, $\eta^2 = .06$). Nonsignificant effects were obtained for AD/HD ($F(1, 93) = 1.93$, *ns*, $\eta^2 = .02$), ODD/CD ($F(1, 93) = 3.36$, *ns*, $\eta^2 = .04$), and the interaction between AD/HD and ODD/CD ($F(1, 93) = .41$, *ns*, $\eta^2 < .01$). These findings indicate that AD/HD, ODD/CD, and the combination of AD/HD and ODD/CD did not explain the number of errors of the ToL.

The results for planning time are illustrated in Fig. 2. The main effects of IQ ($F(1, 93) = .17$, *ns*, $\eta^2 < .01$) and gender ($F(1, 93) = 1.20$, *ns*, $\eta^2 = .01$) were not significant. Children with AD/HD showed faster planning times than children without AD/HD, but the effects of AD/HD hold only for children without comorbid ODD/CD. These findings were supported by significant main effects of AD/HD ($F(1, 93) = 5.06$, $p = .027$, $\eta^2 = .05$) and a significant (interaction between AD/HD and ODD/CD ($F(1, 93) = 8.98$, $p = .004$, $\eta^2 = .09$). The main effects of ODD/CD were not significant ($F(1, 93) = .17$,

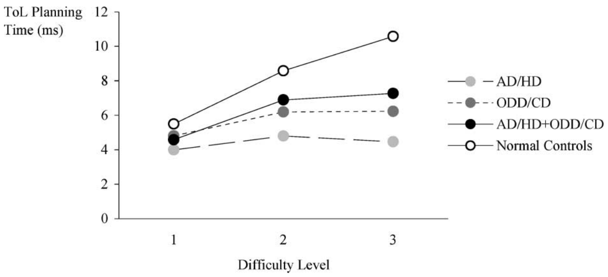

Fig. 2. The effects of difficulty level on planning time in the ToL for children with AD/HD, ODD/CD, AD/HD+ODD/CD and normal controls.

ns, $\eta^2 < .01$). Across groups, planning times increased linearly with difficulty level ($F(1, 93) = 9.25$, $p = .003$, $\eta^2 = .09$). Indeed, as can be seen in Fig. 2, for normal control children planning time increased linearly with difficulty level. In other words: As the difficulty level of the ToL increased, normal controls took longer before making the first move. In contrast, children with AD/HD showed similar planning times across the three levels of difficulty. The performance of children with ODD/CD and children with AD/HD+ODD/CD fell midway between the performance of children with AD/HD and normal control children. This result was supported by a significant three-way interaction between AD/HD, ODD/CD and the linear effects of difficulty level ($F(1, 93) = 4.83$, $p = .031$, $\eta^2 = .05$). Thus, impairments in planning, as operationalized in terms of hasty decision making, seem to be associated with AD/HD but not with ODD/CD nor with comorbid AD/HD+ODD/CD.

The results for execution time are displayed in Fig. 3. Execution times increased with difficulty level and the linear trend ($F(1, 93) = 110.76$, $p < .001$, $\eta^2 = .54$), as well as the quadratic effects were found to be significant ($F(1, 93) = 21.27$, $p < .001$, $\eta^2 = .19$). All other main effects and interactions were not significant. Thus, there

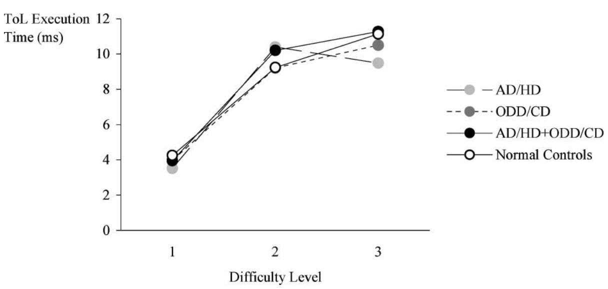

Fig. 3. The effects of difficulty level on execution time in the ToL for children with AD/HD, ODD/CD, AD/HD+ODD/CD and normal controls.

were no differences between the groups in terms of the time needed to execute the sequence of moves in the ToL.

AD/HD Subtypes

Within the AD/HD and AD/HD+ODD/CD group children were categorized as AD/HD inattentive or AD/HD hyperactive/impulsive subtype. Specifically, AD/HD inattentive subtype was defined by: (1) a rating of 12 or more on the Inattention scale of both the parent and the teacher DBD, and (2) a rating lower than 12 on the Hyperactivity/Impulsivity scale by at least one informant. AD/HD hyperactive/impulsive subtype was defined by: (1) a rating of 12 or more on the Hyperactivity/Impulsivity scale of both the parent and the teacher DBD, and (2) a rating lower than 12 on the Inattention scale by at least one informant. AD/HD combined subtype was defined by a rating of 12 or more on both the Hyperactivity/Impulsivity and Inattention scales of both the parent and the teacher DBD. In the AD/HD and AD/HD+ODD/CD groups there were 12 children with AD/HD inattentive subtype and 26 children with AD/HD hyperactive/impulsive or combined subtype. ANCOVAs were conducted to compare these two groups of children and to test the hypothesis that EF deficits would be mainly evident in children with AD/HD combined and hyperactive-impulsive subtype, but not in children with AD/HD inattentive subtype (Barkley, 1997; Milich et al., 2001). These analyses were identical to those described above, except that the between subject factor now was AD/HD subtype. None of the main effects of AD/HD subtype or any of the interactions with AD/HD subtype were significant. Effect sizes were small (range $\eta^2 < .01$–$.03$).

DISCUSSION

The main finding of this study is that, independent of ODD/CD, AD/HD was associated with deficits in planning and working memory, but not in verbal fluency. In the regression analyses, AD/HD explained a significant amount of the variability in the number of errors on the SOPT, the ToL score, the number of errors on the ToL, and ToL planning time. These results were obtained after controlling for the effects of gender, IQ, and ODD/CD. The results with the ANCOVAs paralleled the findings of the regression analyses: Compared to children without a diagnosis of AD/HD, the presence of AD/HD was associated with more errors on the SOPT (regardless of difficulty level), a greater increase in errors with difficulty level on the SOPT, a lower ToL score, and faster planning times on the ToL (regardless of difficulty level). The accompanying effect sizes range from small to large (Cohen, 1988).

In contrast to the findings for AD/HD, the presence of ODD/CD was not associated with performance deficits on any of the tasks in either the regression analyses or the ANCOVAs. On the contrary, some of the present findings suggest that ODD/CD is associated with enhanced performance on measures of EF. Firstly, high parent ratings of ODD/CD were associated with a low error rate on the ToL. Secondly, compared to children without a diagnosis of ODD/CD, the presence of ODD/CD was related to higher ToL scores in the categorical analyses. Thirdly, the presence of comorbid ODD/CD in children with AD/HD was found to reduce the impulsive planning strategy, which was evident in children with AD/HD without ODD/CD. More specifically, children with AD/HD did not adjust their planning time with increasing difficulty level (planning times remained similar across difficulty level), whereas children with comorbid AD/HD+ODD/CD did show some increase in planning time with increasing difficulty level (although not to the same extent as normal controls).

Taken together, the results from the regression analyses and ANCOVAs confirm the hypothesis that AD/HD, but not ODD/CD, is related to EF deficits, thereby lending support to the model proposed by Barkley (1997). The AD/HD effects on EF were independent of the presence or absence of ODD/CD, although one exception should be noted: Impairments in planning, as operationalized in terms of hasty decision making and measured by ToL planning time, seem to be associated with AD/HD but not with ODD/CD nor with comorbid AD/HD+ODD/CD. With the exception of this result for ToL planning time, the present findings support the hypothesis that comorbid AD/HD accounts for the EF deficits in children with ODD/CD (Pennington & Ozonoff, 1996).

With a single exception (ToL score), only teacher rated AD/HD, but not parent rated AD/HD, significantly predicted EF task performance. Partial correlations between teacher rated AD/HD and EF measures ranged from |.22| to |.34|. Similar findings have been obtained in previous studies. For example, Riccio and colleagues (1994) found that teacher ratings of AD/HD and other behavioral problems predicted performance on the WCST, whereas parent ratings failed to do so. The present result also fits with the finding that teachers, as opposed to children and parents, are the optimal informants for AD/HD symptoms (Loeber, Green, & Lahey, 1990; Loeber, Green, Lahey, & Stouthamer-Loeber, 1989; Loeber et al., 1991; Power et al., 1998).

The present study failed to find support for an association between AD/HD and deficits in verbal fluency. Previous studies investigating verbal fluency in children with AD/HD have obtained mixed results. In their review of verbal fluency studies in AD/HD, Pennington and Ozonoff (1996) concluded that verbal fluency tasks do not seem very sensitive to AD/HD. In a recent review, Sergeant et al. (2002) found that six out of nine studies reported a difference between children with AD/HD and normal control children on letter word fluency. Two out of six studies found a difference on semantic word fluency. Thus, studies of semantic word fluency have not reported differences between AD/HD and normal controls. For letter fluency, results of previous studies are somewhat in support of a deficit in AD/HD. Inconsistent findings have also been obtained in more recent studies, with some studies supporting verbal fluency deficits in AD/HD (Mahone, Koth, Cutting, Singer, & Denckla, 2001) and others failing to find evidence for such an impairment (Perugini, Harvey, Lovejoy, Sandstrom, & Webb, 2000; Shallice et al., 2002).

Few studies have investigated verbal fluency in ODD/CD. Three studies reported poorer performance in children with ODD/CD than in normal control children (Déry et al., 1999; Haggerty et al., 1998; Séguin et al., 1995; Speltz et al., 1999). One study failed to find a difference between children with ODD/CD and normal controls (Toupin et al., 2000). In the study by Séguin et al. (1995) the results for verbal fluency were reported as part of composite measures of EF. In the studies by Haggerty et al. (1998), Séguin et al. (1995), and Speltz et al. (1999) the impact of comorbid AD/HD remains unclear. Thus, evidence for a verbal fluency deficit in ODD/CD independent of AD/HD is weak.

The conflicting findings for verbal fluency may be related to differences between studies concerning selection criteria for AD/HD and ODD/CD, comorbidity, the age range of the children, samples size (and hence statistical power to find the hypothesized difference in verbal fluency), and differences in the procedures used to assess verbal fluency. Furthermore, few studies controlled for IQ (including language development and word knowledge as measured by WISC-R Vocabulary), as was done in the study reported here.

The current study found that children with AD/HD were less accurate on the SOPT and showed a greater increase in errors with increasing difficulty level compared to children without AD/HD. The latter finding is strongly suggestive of a working memory deficit. Three other studies have employed the SOPT with AD/HD and normal children. Shue and Douglas (1992) compared AD/HD and normal control children using both abstract designs (as in the current study) and representational drawings. No group differences were found for the abstract designs. For the representational drawings, children with AD/HD committed more rule breaks and more errors than normal controls. Wiers, Gunning, and Sergeant (1998) showed that children with AD/HD committed more errors than normal controls on the SOPT. In a study by Kempton et al. (1999) unmedicated children with AD/HD committed more errors compared with normal children on a computerized version of the SOPT. Interestingly, AD/HD children using stimulant medication did not differ from normal children. Although these studies suggest that AD/HD is associated with a deficit in working memory as measured by the SOPT, none of the studies demonstrated that the performance of children with AD/HD deteriorated to a greater extent with increasing task difficulty level than in normal children. Hence, the results of these previous studies are not necessarily supportive of a working memory deficit.

In the present study, no evidence was found for a working memory deficit in ODD/CD as measured by the SOPT. Although no studies have used the SOPT in children with ODD/CD, previous studies with aggressive subjects are in line with the current results. Giancola and Zeichner (1994) studied the neuropsychological performance of a sample of young adults, but failed to find a relation between aggression and performance on the SOPT. Séguin et al. (1995, 1999) compared aggressive and nonaggressive boys on the SOPT. However, in these studies the results for the SOPT were not reported separately, but as part of a composite measure of EF. Hence, the results for the SOPT isolated from the results of the other EF tasks are not known.

AD/HD was associated with poor performance on the ToL. AD/HD predicted a low ToL score, a high number of errors, and fast planning times (despite normal execution times). Children with AD/HD, but without ODD/CD, had planning times that remained similar across difficulty level. In other words, these children did not adjust their planning time as difficulty level increased. Taken together these results suggest that children with AD/HD performed poorly on the ToL, because they made the first move before they had successfully generated an appropriate solution to the problem. The fast planning times in AD/HD children may be interpreted as impulsive, although the normal execution times on the ToL suggest that this impulsivity does not arise from a tendency toward fast motor responding. This finding parallels previous research in which slow, variable and inaccurate processing characterizes AD/HD children (for review, see Sergeant, Oosterlaan, & Van der Meere, 1999).

A few studies have compared AD/HD children with normal controls on the ToL (Culbertson & Zillmer, 1998; Houghton et al., 1999; Kempton et al., 1999; Nigg, Blaskey, Huang, & Rappley, 2002; Wiers et al., 1998). There have been no studies investigating ToL performance in children with only ODD/CD. Culbertson and Zillmer (1998) found that AD/HD children needed more moves and time to solve the problems and committed more rule violations than normal control children. In a study by Kempton et al. (1999) using a computerized version of the ToL, unmedicated children with AD/HD required more moves to solve the problems than normal children and children with AD/HD using stimulant medication. Nigg et al. (2002) found that children with AD/HD combined subtype, but not children with AD/HD inattentive subtype, obtained lower ToL scores than normal controls. Although this finding suggests that the AD/HD combined subtype carries the ToL deficit, no differences were found when the two subtypes were compared. Two studies failed to find evidence for a planning deficit in AD/HD as measured by the ToL (Houghton et al., 1999; Wiers et al., 1998). Importantly, none of the previous studies have demonstrated a differential impact of difficulty level on AD/HD and normal control children. Hence, previous research does not provide unequivocal support for a planning deficit in AD/HD.

Barkley (1997) proposed the hypothesis that EF deficits are mainly evident in children with AD/HD combined and hyperactive-impulsive subtype, but not in children with AD/HD inattentive subtype. Similarly, Milich et al. (2001) have argued that neuropsychological dysfunctions characterize the combined subtype, but not the inattentive subtype. The present study failed to find any support for this hypothesis. On the contrary: For one of the dependent variables, i.e., SOPT number of errors, the regression analyses showed that it was not hyperactivity/impulsivity ratings, but teacher inattention ratings which accounted for a significant proportion of the variance. No differences were found between subtypes with the ANCOVAs. Although there are some studies that support the hypothesis that the AD/HD combined and hyperactive-impulsive subtypes carry the EF deficits (Houghton et al., 1999; Klorman et al., 1999; Lockwood, Marcotte, & Stern, 2001; Nigg et al., 2002), several studies have failed to show reliable differences between AD/HD subtypes (e.g., Barkley, Grodzinsky, & DuPaul, 1992; Chhabildas, Pennington, & Willcutt, 2001; Faraone, Biederman, Weber, & Russell, 1998; Lockwood et al., 2001). As yet, there is little evidence that EF deficits are specific to AD/HD combined or hyperactive-impulsive subtype.

The EF deficits observed in AD/HD may constitute a risk factor for the maintenance of AD/HD in later development, and possibly for the development of other DBDs including ODD and CD. EF shows a gradual development during childhood, adolescence, and early adulthood. A hierarchical model of development has been suggested in which the maturation of one EF domain is necessary for the development of a second EF domain (Archibald & Kerns, 1999; Welsh & Pennington, 1988; Welsh et al., 1991). For example, Barkley (1996, 1997) suggested that the development of the ability to inhibit a response is a prerequisite for the development of other EF domains such as working memory. Therefore, minor EF deficits evident early in the child's development may cause a cascade of other future EF deficits ultimately leading to gross EF deficits (Lynam, 1998; Moffitt, 1993). Gross EF deficits may translate into severe impairments in the ability to plan, execute, verify, and regulate one's own goal-directed behavior. Minor EF deficits may be caused by hereditary and environmental factors (e.g., poor nutrition, fetal exposure to alcohol, head injury).

An important unresolved issue is whether the EF deficits in AD/HD are a cause or a consequence of this disorder. This question calls for longitudinal research. Furthermore, it is unclear whether the observed EF deficits reflect a maturational lag or a permanent impairment (Kempton et al., 1999; Shue & Douglas, 1992). This issue may also translate to the neurological underpinnings of the EF deficits in AD/HD. A developmental lag would suggest that AD/HD is associated with a delay in the maturation of the brain (possibly the frontal cortex and its subcortical connections), whereas a permanent impairment would suggest a neurological deficit that remains stable across development.

The present study has several limitations. First, although the current results argue against the hypothesis that ODD/CD is associated with EF deficits, aspects of EF not examined in the present study may be impaired in this disorder. Second, although EF measures are designed to assess a specific aspect of EF, most EF measures are critically dependent on non-EF abilities, such as perception, attention and response organization (Eslinger, 1996). In order to conclude that poor performance on a particular EF test pinpoints a deficit in EF, it is necessary to control for the demands that this test exerts on non-EF abilities (Denckla, 1996; Sergeant et al., 2002). By entering IQ in the analyses, this study controlled for the possible confounding effects of some non-EF abilities, but not all. In future research, stringent controls for these non-EF demands are required. This may be done by administering non-EF control measures that cover all relevant non-EF domains or by using EF tasks that have built-in controls for non-EF demands. An example of a task with built-in controls for non-EF demands is the Stroop Task which measures interference control (Stroop, 1935). In this task, the subject has to name the color of mismatching color words (e.g., the color-word red presented in blue). In order to control for word reading speed and color naming speed, subjects are required to name color words and colors. Such an approach allows for a more stringent test of the EF deficits hypothesis for AD/HD and ODD/CD. Third, although this study employed stringent controls for comorbidity in terms of AD/HD, ODD and CD, comorbidity with other disorders, such as anxiety disorders, learning disorders, and pervasive developmental disorders, was not taken into account.

Although the present finding suggests that EF deficits are uniquely related to AD/HD, this finding will be of little utility in the diagnostic classification of individual children. AD/HD and ODD/CD have been found to co-occur frequently (e.g., Angold et al., 1999), and symptoms of ODD/CD will be rarely absent in children with AD/HD. Nevertheless, the present findings provide information in support of theory construction, and may facilitate the targeting of interventions.

Future research should attempt to delineate the underlying dysfunction that gives rise to the EF deficits in AD/HD. One way to address this issue is the use of cognitive tasks that make it possible to disentangle the different cognitive processes that operate in performance on these tasks (Sergeant et al., 1999). Another potentially fruitful avenue of research is suggested by three recent studies (Aman, Roberts, & Pennington, 1998; Kempton et al., 1999; Scheres, Oosterlaan, & Sergeant, 2003). In these studies it was shown that stimulant medication improved EF performance in children with AD/HD, suggesting that EF deficits may arise because of a dysfunction in the catecholaminergic system. Finally, EF tasks may be combined with functional imaging techniques to delineate the brain structures underlying EF deficits in AD/HD.

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